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FERMENTED MILKS.

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INTRODUCTION.

Within recent years there has been a rapidly growing interest in the therapeutic value of buttermilk and other fermented milks, such as kefir, kumiss, and yoghurt. This is seen in the increasing sale of buttermilk, in the large number of special preparations now offered for sale, and in the frequent discussion of this subject in popular and scientific publications. Buttermilk is not only consumed in large quantities as a beverage, but is recommended by physicians as a therapeutic agent in the treatment of intestinal disorders, and is in constant use in many hospitals.

It is the aim of this paper to give the reader a brief résumé of our present knowledge of this subject. The literature relating to fermented milks is already voluminous, and few persons, not even physicians, are so situated that this can be brought together and assimilated. It will be necessary for the benefit of those having a professional interest in the subject to include information of a somewhat technical nature.

All of the more familiar fermented milks are the result of an acid fermentation in which the sugar of the milk is split up into lactic acid. This may be brought about by the presence in the milk of varieties of the common lactic-acid group of bacteria, or, as in the case of yoghurt, by special organisms; or a yeast may be present, adding an alcoholic to the ordinary acid fermentation.

In many large cities special fermented milk preparations can be obtained under various trade names—zoulak, vitallac, yoghurt, matzoon, bacillac, kefir, kumiss, and lacto-bacilline. These are all soured milks which have been introduced from southern Russia, Turkey, and neighboring countries. They are sold as freshly prepared milk, or in the form of tablets or powders in capsules which may be taken directly or used to ferment milk. These preparations have been widely advertised and are the subject of very positive statements in regard to the benefits derived from their use.

Before discussing the various types of fermented milk it will be well to consider briefly the claims made for fermented milks in general, and the actual information on which such assertions are based.

FOOD VALUE OF FERMENTED MILK.

The high food value of milk is too generally recognized to need discussion here; fermented milks also have a high food value, except that in some cases the fat is partially or entirely removed. Otherwise the food value of the fermented milk differs little from that of the fresh milk from which it is made. Any increased digestibility of the fermented milk is due not so much to change in the chemical nature as to the fact that the casein is furnished in a precipitated and finely divided condition. In none of the fermented milks is there any material cleavage of the casein resembling the digestion in the stomach. The fat is almost unchanged, and a part only of the sugar is converted into acid, alcohol, or gas. In certain gastric troubles in which it is difficult to find any food that can be retained by the patient, fermented milks are frequently used with good results. Kefir and kumiss especially are used under such circumstances, as the stimulating action of the carbon dioxid which they contain is believed to aid in their digestion. The value to the physician of a highly nutritious food which can be digested when other foods are rejected is obvious.

THERAPEUTIC VALUE OF FERMENTED MILK.

Fermented milks have been used since very early times, and it is probable that their value in treating intestinal disorders has been known in an indefinite way for centuries, but it is only in recent years that their therapeutic possibilities have been recognized by physicians. The development of bacteriology was necessary to supply the information on which the rational use of this therapeutic agent is based. For the past fifteen or twenty years medical journals have contained occasional papers on fermented milks of various kinds, and at one time the use of kumiss in the treatment of tuberculosis and other diseases was much discussed. The present interest in the subject is largely due to the work of Metchnikoff and his students.

Metchnikoff's views are set forth in a popular way in Chapter V, "Lactic acid as inhibiting intestinal putrefactions," of his book entitled "The Prolongation of Life."[54][a] He relates many marvelous incidents as to the therapeutic and prophylactic value of fermented milk. The narrative of the sailor who was cared for by Arabs who sometimes reached the advanced age of 200 or 300 years on a diet of soured camel's milk is admittedly somewhat exaggerated, but many cases are cited of exceptional longevity presumably through the use of fermented milks. It should be remembered that the peoples who habitually use fermented milks are hardy races living and working in the open air, and while their good health may be due in

[a] Figures refer to bibliography at end of paper.

part to their simple milk diet, it by no means proves that sour milk is the elixir of life as some writers would have us believe.

Fermented milks are now recommended when a nutritious and digestible food is essential, but it is in the treatment of disorders resulting from autointoxication that their chief value is supposed to lie. Autointoxication may be caused by the undue accumulation of poisonous substances which are promptly removed in health. Toxic substances usually found in small quantities may be produced in excess, or, what is more common, toxins may be formed by bacteria in the intestines in amounts too great to be disposed of through the usual channels. These toxic substances are absorbed into the system and produce symptoms which may be merely an uncomfortable feeling of indigestion and headache, or which may assume the more acute form frequently and erroneously spoken of as ptomaine poisoning. This form of autointoxication is usually accompanied by intestinal gas and foul-smelling stools. One symptom of great value to the physician is the excretion in the urine of abnormal quantities of indican and ethereal sulphates.

The phase of autointoxication which the advocates of the use of fermented milk hope to reach is caused by the decomposition of the partly digested food by bacteria. The digestive tract of the human being is normally free from bacteria at birth. In a short time, however, bacteria gain an entrance, and from that time the intestines are never free from micro-organisms. If an infant is breast fed the variety of bacteria is limited, but if it receives cow's milk the number increases more rapidly and the variety is correspondingly greater. Many persons have erroneous ideas in regard to the contamination of foods by bacteria, and statements are sometimes made which have no basis in fact. It is true, however, that any food may act as a carrier of bacteria, although in properly prepared food the number is usually small. There are some exceptions, as, for instance, milk, and there is no difficulty in explaining the presence of bacteria in the digestive tract. The acidity of the stomach is so high and the food is retained so short a time that under normal conditions bacteria do not multiply appreciably there, but are carried into the intestines, where conditions of temperature, chemical reaction, and nutriment are favorable to the rapid development of many kinds of bacteria. Certain kinds of bacteria establish themselves in the intestines, especially in the lower or large intestine, and are found so constantly there that they may be considered as normal inhabitants of the digestive tract. Among those most familiar to bacteriologists are the *Bacillus coli communis* and members of the *Bacterium aerogenes* group. Other varieties may be present constantly or may appear for a short time only, this depending largely on the nature of the food consumed. Most of the bacteria occurring in the intestines are prob-

ably harmless, at least under ordinary conditions. It is not improbable that some of them aid digestion in some way, and may be looked upon as beneficial. On the other hand, unusual varieties may appear, or varieties normally present may be influenced by unusual circumstances to produce changes detrimental to their host. Our knowledge of the bacteriology of the intestines is not yet sufficient to connect intestinal autointoxication with any particular species or group of bacteria, but recent work has indicated that while the normal bacteria of the intestines are of the class growing equally well in the presence or absence of air, autointoxication is coincident with the appearance in the intestines of bacteria growing only under conditions that exclude air. *Bacillus aerogenes capsulatus* is a typical member of this group.

It is not advisable in this paper to consider in any detail the chemical changes that result in the production of toxic substances. It is sufficient to note that it is not necessary to assume the presence of any specific toxin in the ordinary sense of the word. Many products of metabolism which are harmless in small amounts become toxic in excess. The carbohydrates of the partly digested food may be broken up by bacteria into gases, alcohols, and organic acids which are irritating to the delicate mucous membrane. From the proteins may be formed products toxic in their nature. The work of Vaughan and his associates shows that certain of the normal products of digestion may under some combinations of circumstances be split into two substances, one of which is harmless while the other is highly poisonous. Thus slight changes in the course of the decomposition which food undergoes in the intestine may have far-reaching effects on the system.

The use of fermented milk in combating autointoxication is based on the theory that the introduction of lactic-acid bacteria produces conditions unfavorable to the growth of the toxin-producing bacteria. The inhibiting action is believed to be due partly to the acid formed in the milk before it is ingested and partly to the introduction into the digestive system of large numbers of lactic-acid bacteria which become established there and tend to suppress the activities of the bacteria which produce undesirable decompositions.

Turning to the scientific demonstration of the value of sour-milk therapy, we find that most of the evidence is clinical, based on the observation by physicians of the effect of sour milk in various pathological conditions. Numerous instances could be cited of marked improvement of intestinal troubles following the use of sour milk. As has been noted, this action may be due—

(*a*) To the action of the lactic acid contained in the milk at the time it is taken in inhibiting the activities of undesirable bacteria in the digestive tract;

(b) To the growth in the intestines of the bacteria taken with the milk which suppress other forms either by the acid produced or through means not identified with acid formation.

Considering the possible action of the acid of the milk in suppressing undesirable bacterial fermentations, we find that it is well known that the growth of some bacteria can be prevented by acids and that different species of bacteria show marked differences in their tolerance to an acid reaction. Many bacteria fail to grow in a medium only slightly acid. As milk sours the many varieties of bacteria usually present in the fresh milk are eliminated one by one until in the curdled milk one or two forms only are found in appreciable numbers. Some peculiar species, as the vinegar organism, are able to stand comparatively high acidity, but these are exceptional, and vinegar is sometimes used as a preservative, especially in the manufacture of many kinds of pickles. The intestinal flora, however, always includes some bacteria capable of growing in a distinctly acid medium. Moro[57] isolated from the stools of breast-fed infants a bacillus able to grow in whey acidified to 0.9 per cent. *Bacillus coli communis* and members of the aerogenes group, which are almost invariably found in the digestive tract, thrive in a moderately acid medium. These two groups ferment sugars, forming organic acids, large quantities of gas, and sometimes small amounts of alcohol. The ingestion of soured milk would be very unlikely to overcome the natural alkalinity of the intestines sufficiently to inhibit bacteria of this class. Moreover, an increase in the milk used would increase the supply of sugar from which gases could be formed. This condition would be exaggerated by the practice frequently recommended of adding to the diet foods rich in sugar to furnish food for the lactic-acid bacteria.

An acid condition of the intestines is carefully guarded against by the provision for the neutralization of the acid juices of the stomach as they enter the intestine. It is probable that this action is largely automatic and that an increased acidity in the food coming into the intestine would be followed by a corresponding increased flow of alkaline secretion. If it were possible to render the contents of the intestines so acid that bacterial growth would be checked even slightly, the action of the digestive enzyms of this region would be almost or completely stopped and serious consequences would result. It is possible that the intestines may contain bacteria whose growth could be checked by a decrease in the alkaline reaction. There is some clinical evidence favoring the use of lactic acid in cases of intestinal autointoxication, but this is not very conclusive. It seems improbable that the acid contained in any form of fermented milk would be great enough to affect the activities of intestinal bacteria.

However, the efficacy of fermented milk is supposed to depend mainly not on the acid contained in the milk, but on the heavy inoculation of acid-forming bacteria into the intestines and their continued growth there to the exclusion of other forms. The evidence that such a condition can be induced is not altogether conclusive. The advocates of the use of sour milk have used for the most part in their experimental work a peculiar bacterium which forms an exceptionally high percentage of acid and which is said to be particularly adapted to acclimatization in the intestines. This micro-organism is generally known as the Metchnikoff bacillus, the bacillus of Massol, or *Bacillus bulgaricus* (see fig. 4, *a*). Cohendy,[12] who fed four patients for extended periods on milk curdled with *B. bulgaricus*, concluded that this organism became readily established in the intestine and that it persisted there for a considerable time after the subject had ceased to take fermented milk. This was said to be especially true if a diet were adopted containing suitable nourishment for the ingested organism. It is stated that the multiplication of these bacteria took place in the upper two-thirds of the colon. The stools were acid or neutral. The same writer in another paper[14] shows that intestinal putrefaction as indicated by the excretion of ethereal sulphates in the urine was materially reduced by the addition of a sour milk to the diet, and that this reduction, which may reasonably be attributed to a disinfection of the large intestine, continued after the ingestion of sour milk was discontinued. This may be taken as an indication that the growth of the bacteria continued after their introduction ceased. This disinfecting action of the lactic-acid culture was not appreciably influenced by variations in the amount of sugar eaten, indicating that the ordinary diet contains sufficient sugar to support the growth in the intestines of the lactic bacteria.

Belonovsky[3] studied the effect of the *Bacillus bulgaricus* on the intestinal flora of mice. In his experiment several lots of mice were fed on a basic ration of sterilized grain and water, and to the ration of two of these lots were added milk cultures of the *B. bulgaricus*. Mice fed on this ration one and one-half months showed this organism in the droppings fifteen days after the last feeding; with animals fed the culture for four months it was present for four weeks after the last feeding.

On the other hand, Herter[39] found that in the digestive tract of a monkey killed after feeding for two weeks on milk soured with *B. bulgaricus* this organism was abundant in the upper part of the small intestine only. In the lower part of the small intestine and in the large intestine *B. bulgaricus* was present in only moderate numbers as compared with other bacteria.

Heinemann and Hefferan[34] found an organism answering to the description of *B. bulgaricus* in ordinary milk, in feces of cows, horses,

and man, and in soil, grains, and pickles. They consider that it is normally present in small numbers in the digestive tract and even suggest that it may cause pathological conditions under certain circumstances. The inference may be drawn from their work that since this organism is so widely distributed it must be taken into the digestive system almost continuously, and if it were adapted to growth in the intestines it would become established there in the natural course of events. The small amount of acid formed by their cultures in milk at 37° C. (98.6° F.) shows that they were much less active than the cultures used in making fermented milks. The most active of their cultures formed in three days only a little more than 1 per cent of lactic acid. A typical culture forms in this time at 37° C. nearly or quite 3 per cent.

It must be admitted that up to the present time the investigations have not conclusively demonstrated that it is possible to establish the lactic-acid bacteria in the intestines with any permanency.

From the cases cited or from the numerous clinical observations in which distinct benefit has resulted from the use of fermented milk it does not seem necessary to assume that the multiplication of this class of bacteria in the intestine is essential to the success of this treatment. It is very well known that bacteria excrete substances having a retarding influence on the growth of other bacteria and that in some cases at least this result is not due to acids. It is possible to explain the disinfecting action of fermented milk by assuming the existence of substances of this kind which are formed in the milk and introduced into the digestive system in amounts sufficient to have an appreciable effect on the bacteria of the intestines.

Belonovsky in the work already cited found that while there was no reduction in the intestinal bacteria in mice fed with sterilized milk or with sterilized milk curdled with lactic acid, the two lots fed milk cultures of *B. bulgaricus* showed a distinct reduction in the number of bacteria in the droppings. This was also true of the lot fed with similar cultures sterilized by heat. The diminution was especially evident in the bacteria forming gas and bringing about putrefactive changes. The evidence of the bacterial examination of the stools was confirmed by the changes in weight of the animals while under experimentation. In the two check lots receiving sterilized grain and water, in the lot receiving milk soured with acid, and in that fed sterile milk there were losses in weight; in the two lots fed with milk culture there was a decided gain; and in the lot receiving the sterile culture there was no change in weight. These observations would indicate, although they by no means prove, that the disinfecting effect is due not to the lactic acid, but to the presence in the fermented milk of some by-product having an antiseptic action on certain kinds of bacteria.

The conclusion of Belonovsky that products other than lactic acid play an important rôle are in accordance with the numerous clinical observations of North.[61] His paper on this subject covers observations on many cases of rhinitis, ethmoiditis, and other pathological conditions involving the formation of pus, which were treated with cultures of *B. bulgaricus* used as a spray or wash. In a high percentage of cases this treatment resulted in improvement and frequently in a complete cure. While this work was not controlled by checks to determine the part played by lactic acid or other factors, it is much easier to explain effects of this kind on the basis of a specific antiseptic body than by attributing it to the action of a dilute acid. Conradi and Kurpjuweit[16] have demonstrated that bacteria of the *Bacillus coli* group excrete substances which are antiseptic not only to other bacteria but, when they accumulate in sufficient quantities, to the bacteria secreting them. It is very probable that this is also true of lactic-acid bacteria. It should be stated, however, that the work of Conradi and Kurpjuweit has not been accepted as entirely correct. Kern[43] claims to have separated from cultures of *B. bulgaricus* a substance having a distinct inhibiting action on *B. coli communis*.

While there is no doubt that the benefits to be derived from the use of fermented milk have been greatly exaggerated, especially by those financially interested in an increased use of these preparations, there can be no question that in some cases, at least, much good has resulted from their use. To whatever action of the milk this effect is due, there is abundant evidence to show that putrefactive changes in the colon, with their accompanying symptoms, have in many cases been checked by the addition to the diet of some form of soured milk. Herter[38] found that an increase of ethereal sulphates and indican followed the ingestion with the food of cultures of the colon bacillus and *B. proteus vulgaris*. These indicators of intestinal putrefaction were diminshed by a diet of bread and milk, and cultures of lactic-acid bacteria usually produced a marked decrease. Results of a similar nature have been obtained by others, notably by the associates of Metchnikoff. To this could be added many observations by physicians cited in the medical journals.

It is probable that in many cases an improvement in health following the use of fermented milk may be due not so much to the action of the acid-forming bacteria as to a marked change in the dietary incidental to the use of the milk. Herter and Kendall[40a] found that the nature of the bacterial flora of the intestines could be promptly and distinctly changed by a radical change from a diet high in protein to one in which carbohydrates predominated, or vice versa. A high protein diet caused symptoms of intestinal putrefaction. A change to a carbohydrate diet resulted in a reduction of the putrefac-

tive bacteria, an increase in the acid-forming bacteria, and the disappearance of the indications of autointoxication.

There are many questions that should be very carefully considered before a fermented milk is introduced as an important part of one's diet. As Herter[39] has pointed out in the admirable paper already cited, the addition of fermented milk to the diet may change very materially the ratio of protein to other classes of food. If the milk is taken in place of other food, the daily protein ration may be so reduced that intestinal putrefaction, which is dependent on the protein part of the food, is diminished. On the other hand, if milk is added to the usual food, the protein ratio will be increased rather than diminished. In many cases the condition of the mucous membranes will not permit the presence of organic acid, and soured milk can not be retained. It is also possible that symptoms of autointoxication are due not to unusual bacterial activity in the intestine, but to functional failure of certain organs. This point could be determined only by a physician. It would be very unsafe to consume large quantities of milk, fermented or unfermented, under certain pathological conditions. In any case an important change in one's diet should be made only upon the advice of a physician.

THE VARIOUS FORMS OF FERMENTED MILK.

If it is considered advisable to use cultures of acid-forming bacteria, the form in which these are taken becomes an important question. In large cities one usually has a choice of lactic-acid bacteria from several sources. Buttermilk is usually available, although it is not always of good quality. Sometimes kumiss or kefir can be obtained, and at the present time milk coagulated with the so-called Metchnikoff bacillus is sold as yoghurt or matzoon and under various trade names.

CULTURES IN TABLET AND CAPSULE FORM.

In addition to these freshly prepared preparations several tablets or capsules purporting to be pure and active cultures of the *Bacillus bulgaricus* are now offered for sale. These are for use in fermenting milk or are to be taken directly in place of buttermilk or yoghurt. Herschell[37] in his little book on the therapeutic uses of soured milks recommends the use of these preparations in preference to fermented milk, but it should be noted that he is very explicit in his statement that great care should be taken to determine the abundance and purity of the desired organism. Three brands of these tablets purchased at drug stores in Washington have been examined in the Dairy Division laboratory. It was found that while some of them sometimes contained the Metchnikoff bacillus it was present in such very small numbers that it could be detected only with difficulty. When

these tablets were added to sterile milk they never, even under the most favorable temperature conditions, produced a clean acid curd. The milk was curdled, but with a rennet curd, and showed every evidence of the presence of peptonizing and gas-forming bacteria and yeasts. One tablet which was advertised to contain "5,000,000 active Metchnikoff units" was found to contain something over one million bacteria, nearly all of which were of the class usually considered as undesirable inhabitants of the digestive tract.

It is very easy to test the purity and activity of these dried cultures. Thoroughly pasteurize a small quantity (about half a pint) of milk by holding it, in a bottle plugged with cotton, at or near the boiling point for an hour or more. When this has cooled add two or three of the tablets and keep in a very warm place overnight. It should not be below and may be a few degrees above blood heat. If in this time the milk has not curdled with a sharp acid taste and without gas bubbles and whey there can be no reason for using these tablets except the possibility that they contain the active element of the culture which retards the growth of other bacteria. The evidence on this point is so inconclusive that it need not be considered in this connection.

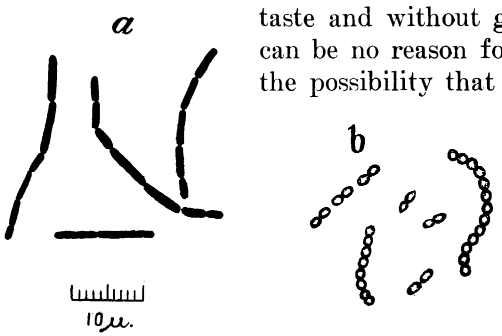

FIG. 4.—Organisms causing fermentation of milk. *a, Bacillus bulgaricus; b,* lactic-acid bacteria.

The results of examinations of these and similar tablets and powders reported by other laboratories agree with the observations of the writer in indicating that at the present time little dependence can be placed on dried cultures of *B. bulgaricus.*

BUTTERMILK.

Buttermilk, properly speaking, is the by-product resulting when milk or cream is churned for butter making. It is the milk remaining after the fat has been collected in globules and removed. If cream is churned when sweet the buttermilk does not differ from ordinary skimmed milk, but if it is churned when sour—the usual practice—the acidity is sufficient to coagulate the casein in the cream. In the churning process this curd is broken up into very fine particles. These curd particles settle very slowly, and if the buttermilk is agitated occasionally it will retain its milky appearance. When the buttermilk is allowed to stand undisturbed for several hours the curd particles sink to the bottom leaving an opalescent whey at the top. At the present time a large part of the buttermilk sold in cities is not made by churning cream, but is simply soured skimmed milk

which has been churned or stirred in order to break up the curd. The same product is sold also under the name of ripened milk.

The souring of milk or cream is brought about by the activity of certain bacteria which form lactic acid by decomposing the milk sugar (lactose). The ability to form acid from lactose and other sugars is possessed by many kinds of bacteria, but is so characteristic of a certain group that they are commonly spoken of as the lactic-acid bacteria (see fig. 4, *b*). These bacteria have been described as distinct species or varieties under many names. Among these may be mentioned *Bacterium guntheri*, *Bacillus acidi lactici*, *Streptococcus lacticus*, and many others. In spite of the confusion in nomenclature it is evident that the term "lactic-acid bacteria" includes a fairly well-defined group of closely related varieties possessing in common several definite characters. Variations from the type in minor characters produce an almost infinite number of varieties. These variations may be in the ability to ferment different sugars, in the tendency to grow in chains, in the kind of flavor formed in milk, in the intensity of acid formation, and in the ability to produce pathological conditions in animals.

In many creameries the cream is allowed to sour spontaneously. In this case many bacteria other than the true lactic bacteria will take part in the acid formation, and in addition to lactic acid the buttermilk may contain in small quantities acetic, succinic, and formic acids, and sometimes traces of alcohol. The lactic bacteria form lactic acid, with only slight traces of other organic acids, no alcohol, and no gas. In well-managed creameries the acid fermentation is assisted and controlled to some extent by the use of a starter. This may be good milk allowed to sour spontaneously, or buttermilk from the previous day's churning, but careful butter makers build up starters from commercial cultures. These cultures are sold in the form of powders, tablets, or fluid cultures, as varieties of lactic-acid bacteria selected with special reference to the production of a desirable flavor in butter. The butter maker puts this culture in about a quart of milk which has been steamed for an hour or more to reduce the bacteria to the lowest possible number. After standing overnight this milk will usually be curdled, but gas bubbles and other evidences of contamination may be observed. A small portion of this milk is transferred to another bottle of milk prepared as before, and this process is continued until the acid fermentation has become sufficiently active to eliminate the contaminating bacteria, and the milk curdles with a clean acid taste and without signs of gas or "wheying off." This small starter, or "mother starter," is carried along indefinitely by daily transfers to freshly steamed milk. If reasonable precautions are taken to prevent contamination and to insure the thorough heating of the milk, this culture will remain pure and vigorous for an indefinite time.

To prepare the starter actually used in ripening the cream, a larger lot of milk—25 to 50 gallons or more, according to the amount of cream—is heated for an hour or more. This is usually done in a special apparatus (sold by creamery supply houses) which consists of a large can inclosed on the sides and bottom by a steam jacket and fitted with a belt-driven stirrer. Milk either skimmed or unskimmed is heated by turning steam into the jacket; during the heating the milk is stirred constantly. After the pasteurization is completed cold water is run into the jacket and the milk cooled to about 24–27° C. (75.2–80.6° F.). A bottle of the mother starter is added and the can is covered and allowed to stand overnight. This gives a large and active pure culture of lactic-acid bacteria to start the acid formation in the cream. More uniform results are obtained if the cream is first pasteurized.

When lactic-acid bacteria grow in milk the lactose is converted into lactic acid with slight traces of certain other organic acids. This acid breaks up the combination of calcium phosphate and casein which holds the casein in solution, and the casein is precipitated as a firm jelly-like mass. When this occurs in cream the fat globules are entangled in the precipitated casein. In the process of churning the casein is broken into fine particles and the fat globules are collected into large granules that float on the top of the buttermilk. Buttermilk, then, is the water of the milk holding the sugar, acids, ash, and other soluble constituents in solution and the finely divided particles of precipitated casein in suspension. The amount of fat in the buttermilk depends on the thoroughness with which the fat is collected in the churning. Even with the best methods a little of the fat in the form of very small globules remains in the buttermilk. On standing, the suspended casein settles slowly to the bottom.

The composition of an average buttermilk is about as follows:[a]

	Per cent.
Fat	0.5
Casein	2.4
Albumen	.6
Lactose	5.3
Ash	.7
Total solids	9.5

Chemically, buttermilk differs but little from milk. Only a slight rearrangement is necessary to bring about the physical change in the casein. If the milk has been pasteurized at a high temperature, the albumen is precipitated and the larger part lost. A small part—less than one-fifth—of the milk sugar is converted into acid. This acid combines with the ash constituents, probably converting the tri-

[a] Vermont Agricultural Experiment Station. Annual Report, 1891, p. 119.

phosphates to di-phosphates and mono-phosphates and the di-phosphate to mono-phosphate. It is obviously not necessary to make butter in order to secure a perfect substitute for buttermilk. Soured skim milk has all the chemical properties of buttermilk, and if it is thoroughly agitated in order to break up the curd it agrees in appearance and flavor with buttermilk obtained by churning cream.

In making buttermilk from milk the same procedure should be followed as in making a starter for cream ripening. A good, clean-flavored "mother starter" should be carried along with every possible precaution to prevent contamination. Good commercial cultures can be obtained, but if it is not convenient to use one of these a natural starter can be secured. For this purpose select milk from several sources, put it into steamed bottles or glass jars, and allow these samples to stand in a warm place until they have soured. Prepare milk for inoculation by steaming or holding a sufficient number of bottles of clean, fresh milk in boiling water for about an hour. When these are cool add to each one from 5 to 10 per cent of milk from those samples that have given the curd with the least evidence of contamination and the most agreeable acid taste. The first sample should contain a high percentage of lactic-acid bacteria. In the second transfer these develop quickly and other varieties are soon suppressed by the acid formed. If there is no added contamination, extraneous forms should soon be entirely eliminated.

After three or four transfers one of these at least should sour in twelve or fifteen hours at room temperature with a clean-flavored acid curd. Gas bubbles or the separation from the curd of a milky or straw-colored whey show that the lactic-acid bacteria are still mixed with other kinds. Considerable variation in flavor can be found in different cultures, and care should be exercised to select one that gives a clean and sharp taste.

Milk to be used for making buttermilk should be fresh and clean flavored. Good buttermilk can not be made from milk that is tainted or too old to be used for other purposes. Skimmed, partly skimmed, or whole milk, as desired, may be used. More uniform and satisfactory results can be secured by destroying the bacteria as completely as possible. If a continuous pasteurizer is used for this purpose the milk should be heated to 82° C. (180° F.) or 85° C. (185° F.). If cans or other holding devices are used—and this method is to be preferred—the milk may be heated to 82° C. (180° F.) or more and held for thirty minutes to an hour. The scorched taste which results from pasteurization at this temperature is not objectionable, as it is obscured by the acidity of the soured milk. The time of the inoculation may be arranged to suit the convenience of the maker and can be determined by experience in each individual case. Using the same culture and holding the temperature uniform,

the amount of the starter can be adjusted to bring the acidity to the curdling point at any definite time within narrow limits. The temperature of the milk should be between 21° and 24° C. (70° and 75° F.). More rapid development of acid can be obtained at higher temperatures, but at the lower temperatures the lactic-acid bacteria are more successful in checking the growth of digesting and gas-forming bacteria. At lower temperatures and with a slower development of acid the casein is precipitated in a finer and more friable curd than at temperatures inducing a more rapid acid production. As soon as a fine curd has been formed the milk should be cooled promptly to below 50° F. to prevent the contraction and toughening of the curd. The curd should be thoroughly broken up by churning as soon as the milk has cooled to the proper temperature. The buttermilk is then ready for bottling, and should be smooth, free from lumps, and show a separation of whey and curd only on long standing.

A more uniform product can be obtained if it is made on a large scale, and if good buttermilk can be purchased from a reliable milk dealer at a reasonable price it is not advisable to attempt to make it on a small scale. However, it is possible to make buttermilk in the home by following in a small way the directions for making buttermilk on a commercial scale. It is necessary first to secure a culture or starter, which is merely milk containing the lactic-acid or sour-milk bacteria free or very nearly free from other kinds. These bacteria are present in any normal milk, and it is only necessary to provide conditions favoring their growth to obtain them in a state of purity. To secure this starter or culture the following procedure should be followed: Steam or boil a bottle holding 4 to 8 ounces for half an hour; fill it two-thirds full of fresh milk and put in a plug of cotton or cover with an inverted glass. Hold this at the ordinary room temperature until the following day, when a second bottle should be prepared in the same way. Put this bottle of milk in water, bring the water to a boil, and hold in this way for about an hour. After cooling to below blood heat add a teaspoonful of the milk from the first bottle. On the following day a third bottle of milk should be heated and inoculated from the second bottle. If the third bottle does not give a curd with a clean acid taste free from gas and whey it should be discarded and the entire process repeated. After the culture is obtained it is not necessary to maintain a small starter to inoculate the milk to be soured for use. Start the buttermilk by heating a quart bottle or jar of milk in boiling water at least a half hour. Cool to below blood heat and add a tablespoonful of the soured milk from the small bottle. When this has soured cool the milk by setting the jar on ice or in cold water, and break up the curd by shaking. Start the buttermilk for the following day with a tablespoonful of this buttermilk, or pour the buttermilk from the bottle

in which it is made, and without washing fill the bottle with heated and cooled milk to sour for the following day. Sufficient sour milk will cling to the sides of the bottle to inoculate each succeeding quantity. One of the vacuum jacketed bottles will be found very convenient for this purpose because the milk can be held at a nearly constant temperature favorable to the growth of the lactic-acid bacteria.

Butter makers in the Northwest make a very refreshing and nutritious drink by adding sugar and lemons to buttermilk. As the casein is already precipitated, the acid juice of the lemon has no effect. Slightly more sugar and lemon juice are necessary than in making ordinary lemonade, and the mixture should be well iced.

KEFIR.

Fermented milks have evidently been extensively used by the people of southern Russia, Turkey, the Balkan countries, and their neighbors for many centuries. The natives have no records and few traditions of the origin of the milks they use, and it is probable that their preparation and use developed gradually by accident and cumulative experience. One of the first of the fermented milks known to Europeans was the kefir, made in the Caucasus Mountains and neighboring regions from the milk of sheep, goats, and cows. Kefir differs from most of the fermented milks of the Mediterranean countries in that it is made from a dried preparation and contains considerable quantities of alcohol and gas. Kefir is made by many tribes under varying names, as "hippe," "kepi," "khapon," "kephir," "kiaphir," and "kaphir," all of which are said to come from a common root signifying a pleasant or agreeable taste.

The mountaineers of the Caucasus depend for a large part of their food on kefir, which they prepare in leather bottles made from the skins of goats. In the summer the skins are hung out of doors either in the sun or in the shade according to the weather, but in winter they are kept in the house. The bags are usually hung near a doorway, where they may be frequently shaken or kicked by each passer-by. Fresh milk is added as the kefir is taken out, and the fermentation continues. Made and propagated in this way, foreign bacteria become mingled with the essential bacteria of the grains, and abnormal and frequently disagreeable flavors result. When the milk is drawn off, in order to prevent the escape of gas, a string is first tied around the neck of the leather bottle, so that the small part wanted for use is held between the stricture and the opening. In the villages and the low country kefir is made in open earthen or wooden vessels and most of the gas escapes.

Small, yellowish, convoluted masses are observed in kefir, which are called seeds or "grains." These grains consist of a central fila-

ment of two parts, of which the outer spreads out, forming the convoluted polyp-like exterior. These parts are built up one upon another, giving the large grains a coral-like appearance. The central part is made up of a mass of bacterial threads. In the exterior, yeast cells are found mingled with the bacteria. When the grains are added to milk they swell and increase in size by forming new grains. At the beginning of the fermentation they settle to the bottom, but in a short time they are carried to the surface by attached bubbles of gas. If the fermentation is active, a thick layer will be formed on the surface, but on shaking or stirring this layer settles again to the bottom.

The biology of kefir was studied by Kern [42] in 1881; but, owing to the faulty technique of that day, his descriptions are evidently erroneous.

Freudenreich [23] describes four organisms that he isolated from kefir grains. One of these was a yeast which he designated *Saccharomyces kefir;* this he found to grow best at 22° C. (72° F.), but not at all at 35° C. (95° F.). It ferments maltose and cane sugar, but not lactose. It gives a peculiar flavor to milk, but causes no fermentation. The cells are oval, 3 to 5 microns by 2 to 3 microns. It is not identical with the ordinary beer yeasts. Two of the organisms were of the lactic-acid bacteria type, but differed from them in forming gas in lactose media. The most interesting of the organisms described is a long, slender bacillus corresponding to one described by Kern as *Dispora caucasica* and to which Freudenreich gave the name *Bacillus caucasicus.* In morphology, failure to grow on ordinary laboratory media, and in high acid production in milk, this bacillus resembles very closely the bacillus mentioned later in connection with yoghurt as *Bacillus bulgaricus.* If Freudenreich's description is accurate, *B. caucasicus* differs from *B. bulgaricus* by forming gas from lactose and in being feebly motile. At 35° C. (95° F.) it produced 0.2025 per cent of acid in nine days. Gas was formed slowly at this temperature and still more slowly at 22° C. (72° F.). No one of these organisms alone produced kefir, but when the four together were grown in milk typical kefir was produced on the first or second transfer.

According to the investigations of Nikolaiewa,[60] three organisms are always present in the fermented milk. One of these, *Bacterium caucasicum*, which forms the filament of the grain, is evidently identical with Freudenreich's *Bacillus caucasicus.* This investigator considers this bacterium, with a torula yeast fermenting lactose, dextrose, and cane sugar, as essential to the production of kefir. Other bacteria and yeasts are found in the grains and the fermented milk, but they are looked upon as contamination.

It is probable that kefir is produced under different circumstances by different organisms. Any combination of bacteria or of bacteria and yeasts that will produce a lactic-acid and a mild alcoholic fermentation in milk will make kefir, although to secure the most desirable flavor certain organisms may be essential.

Hammarsten [29] shows the changes brought about in cow's milk by this fermentation in the following table:

Chemical analysis of kefir.

	Two days old.	Four days old.	Six days old.
Casein	2.570	2.586	2.564
Lactalbumen	.425	.405	.390
Peptones	.071	.089	.120
Lactose	3.700	2.238	1.670
Fat	3.619	3.630	3.626
Ash	.641	.624	.630
Lactic acid	.665	.832	.900
Alcohol	.230	.810	1.100

It will be observed that the changes were confined almost entirely to the lactose and its by-products. The casein remained unchanged and the increase in the peptones was insignificant. The lactalbumen decreased slightly. The casein of kefir is, according to this chemist, not especially soluble, but may be more easily digestible because of its finely divided condition. The lactose diminished appreciably, and there was a corresponding augmentation of alcohol and lactic acid. A certain part of the lactose is consumed in the formation of carbon dioxid gas not included in this analysis.

The following directions are given for making kefir when the grains are available: The dry grains are softened by soaking in warm water, which should be changed several times. When the grains rise to the surface and become white and gelatinous they are ready for use. One part of these grains is used to three parts of milk which has been thoroughly heated to destroy the bacteria already present. The bottles in which the milk and grains are placed should not be stoppered but should be protected from the dust by cloths, inverted cups, or plugs of cotton. They are held at a temperature at or near 14° to 16° C. (57° to 60° F.), and stirred or shaken frequently. After eight to ten hours the milk is strained through cloth and put in tightly stoppered bottles at the same temperature as before. The bottles should be shaken every few hours to prevent the formation of lumps of precipitated casein. The kefir is ready for use at the end of twenty-four hours. If it is held longer than this it is advisable to keep it on ice to check the fermentation. The temperature at which the milk is fermented is important in controlling the relative amounts of alcohol and lactic acid. At higher temperatures the percentage of alcohol is increased, while as

the temperature is lowered the alcoholic fermentation diminishes and the quantity of lactic acid formed is greater. After the fermentation is once started the grains may be discarded and new kefir made by adding one part of the fermented milk to three or four parts of fresh milk. In order to remove the grains the kefir should be strained through cheese cloth, and after thorough washing to remove the curd the grains may be dried by exposure to the sun on pieces of blotting paper. In this condition they are said to retain their vitality for several years, although many of the yeasts in the outer part of the grain are killed by the desiccation. It may be necessary to break up the grains with the fingers. They should not be larger than a walnut when in the wet stage.

Kefir grains can not ordinarily be obtained in this country, but a good imitation of kefir can be made by carrying on simultaneously in sealed bottles an alcoholic and a lactic fermentation. Better results can be obtained by inducing the alcoholic fermentation in buttermilk. In this way it is possible to avoid much of the trouble from the formation of lumps of curd. If buttermilk is made for this purpose from whole or skimmed milk, careful attention should be given to the time of curdling and the breaking up of the curd. This is essential to a smooth, creamy kefir. Ordinary bread yeast may be used for the alcoholic fermentation, but as this yeast does not ferment lactose it is necessary to add cane sugar to the milk. Prepare the yeast on the day before the buttermilk is ready by adding a half teaspoonful of sugar to a 6 or 8 ounce bottle of boiled and cooled water. Add half of a yeast cake to this sugar solution and set in a warm place overnight. This will give an active culture of the yeast and obviates the necessity of adding the yeast cake directly to the milk.

On the quantity of sugar added to the buttermilk will depend the extent of the alcoholic fermentation. Theoretically about one-half of the sugar fermented may be converted to alcohol; that is, milk to which 1 per cent of cane sugar has been added may contain after the fermentation one-half of 1 per cent of alcohol. The quantity of sugar added should be governed by the amount of carbon dioxid it is desired to have in the finished product. This should be sufficient to make the kefir distinctly effervescent and impart to it the peculiar sharp taste of charged water, but should not be developed enough to blow the fluid out of the bottles when the stoppers are removed. Experience shows that 1 to 1½ per cent of sugar will give the right amount of gas. This may be approximated by adding sugar in the proportion of 2 even teaspoonfuls of sugar to each pint of milk.

Having the buttermilk and the yeast culture ready, dissolve the sugar in the buttermilk and add the yeast culture in the proportion of 1 teaspoonful to a quart of buttermilk. Mix thoroughly and

bottle. The bottles should be very strong, as sufficient gas pressure is sometimes generated to break ordinary bottles. The heavy bottles used for ginger ale or other carbonated drinks answer this purpose very well. The bottles should be carefully cleaned and boiled or steamed before filling. Fill them full and stopper tightly, wiring or tying the stoppers securely in place.

The alcoholic fermentation should be carried on at a comparatively low temperature. If the fermentation is too active the kefir will have a yeasty taste and the curd is likely to become lumpy and filled with large gas bubbles. A temperature of 18° C. (65° F.) to 21° C. (70° F.) will be found satisfactory for kefir which is to be used on the third or fourth day. The floor of a cool cellar is a convenient place to ferment kefir made in the home. The bottles should be shaken as often as may be necessary to keep the curd in a finely divided condition. The finished product should be smooth and creamy, effervesce rapidly when poured from the bottle, and have the pleasant acid taste of buttermilk with the added sharpness due to the gas and the trace of alcohol. Kefir 2 or 3 days old may have a yeasty taste, but if it has been properly made this will disappear as the fermentation of the sugar nears completion. Kefir made under these conditions should be used when 3 to 5 days old, but if it is put on ice it may be held for a week or even longer.

KUMISS.

The missionary monks and other wanderers who first penetrated the undulating, treeless plains of European Russia and central and south-western Asia brought back descriptions of a fermented drink which in the light of more recent investigations is easily recognized as kumiss. These vast prairies are inhabited by tribes of nomads who live in squalid huts or tents in the winter and wander during the summer, seeking pasture for their horses, their herds of cattle, or flocks of sheep. They are all horsemen, and by a process of selection in which they have probably played only a passive part have developed an exceptionally hardy race of horses. The mares give much more than the ordinary amount of milk, which constitutes almost the entire food of the people during the summer. This is never used in the fresh condition, but is fermented to make kumiss. Unlike kefir, there is no dried "ferment," "seeds," or "grains" with which the fermentation of the mare's milk is started. It is the practice of the natives, when it becomes necessary to establish the fermentation anew, to add to milk some fermenting or decaying matter, such as a piece of flesh, tendon, or vegetable matter. Whatever the material used to supply the essential organisms, it is evident that the milk is so cared for that a combination of an acid and an alcoholic fermentation is favored and the necessary bacteria and yeasts are soon established.

No doubt the change in the milk is produced under different circumstances by different combinations of bacteria and yeasts, and there are usually present various contaminating organisms which are detrimental or at least are not essential to the production of the kumiss. Native kumiss makers lay great stress on the quality of the milk, the breed of the mares, and the condition of the pastures; but it is probable that their troubles ascribed to variations in these conditions are more likely due to imperfectly controlled bacteriological factors.

There was at one time much interest in kumiss as a therapeutic agent in the treatment of tuberculosis, and sanatoria were established in Russia where invalids could be given this treatment. It is probable that the benefits, real or imaginary, derived from this treatment came more from the general methods, which corresponded somewhat to present practices, than to the action of kumiss.

Mare's milk is lower in nutritive value than cow's milk, as the following table, taken from Richmond's Dairy Chemistry, shows:

Average composition of cow's milk and mare's milk.

<table>
<tr><th></th><th>Water.</th><th>Fat.</th><th>Sugar.</th><th>Casein.</th><th>Albumen.</th><th>Ash.</th></tr>
<tr><td></td><td>Per cent.</td><td>Per cent.</td><td>Per cent.</td><td>Per cent.</td><td>Per cent.</td><td>Per cent.</td></tr>
<tr><td>Cow</td><td>87.10</td><td>3.90</td><td>4.75</td><td>3.00</td><td>0.40</td><td>0.75</td></tr>
<tr><td>Mare</td><td>90.06</td><td>1.09</td><td>6.65</td><td colspan="2">1.89</td><td>.31</td></tr>
</table>

The composition of kumiss varies somewhat with the age, the rapidity of the fermentation, and the nature and extent of contamination with extraneous organisms. The following analysis is taken from Richmond's Dairy Chemistry (p. 241):

Composition of kumiss made from mare's milk.

	1 day old.	8 days old.	22 days old.
	Per cent.	*Per cent.*	*Per cent.*
Water	91.43	92.12	92.07
Alcohol	2.67	2.93	2.98
Lactic acid	.77	1.08	1.27
Sugar	1.63	.50	.23
Casein	.77	.85	.83
Albumen	.25	.27	.24
Albumose	.98	.76	.77
Fat	1.16	1.12	1.30
Ash	.35	.35	.35

It will be observed that this fermentation produces no changes that could be expected to increase appreciably the digestibility of the nitrogenous part of the milk except the possible advantage of a finely divided curd. Mare's milk differs from cow's milk in giving with rennet a softer, more friable curd, but it is not certain that this property would increase the value of kumiss.

Kumiss is often made and offered for sale in this country, but as this is usually made from cow's milk, it is, more correctly, kefir.

YOGHURT, ETC.

In passing to a consideration of the fermented milks used by the people of the countries bordering on the eastern end of the Mediterranean we find a preparation very distinct from that of the Caucasus and the Russian steppes. Kefir and kumiss are limpid, mildly acid, and distinctly alcoholic; but the yoghurt, yahourth, or jugurt of the Turks, the kissélo mléko of the Balkan people, the mazun of Armenia, the gioddu of Sardinia, the dadhi of India, and the leben or leben raib of Egypt are all thick curdled milks, decidedly acid, and with very little or no alcohol. The method of preparation is also quite different. Goat's, buffalo's, or cow's milk may be used. This is usually boiled and sometimes is reduced by evaporation to one-half its original volume. In the latter case it is not used as a drink, but is eaten, frequently with the addition of bread, dates, or other food.

A portion of the previously fermented milk is used to ferment the fresh milk. Unlike kefir, there are no "seeds" through which the fermentation can be transmitted, but the essential organism is sometimes preserved by drying the fermented milk and reducing the dry material to a powder. This constitutes the "podkwassa," or "maya." The organism giving these milks their distinctive character is evidently identical in all of them, or, more properly speaking, may be any one of the several varieties of a distinct and closely related group. On account of its peculiarities, some of which are exceptional and striking, and the importance recently attached to it by the discussions both in the scientific and the popular press, a brief résumé of its characteristics is given:

This bacterium was probably first observed by Kern,[42] who incorrectly designated it *Dispora caucasicum*. His description, however, is so limited that it is impossible to attach the name he proposes to any particular organism. Later Beyerinck,[6] under the name *Bacterium caucasium*, and Freudenreich,[23] as *Bacillus caucasicus*, described organisms isolated from kefir which agree in their essential features with those obtained from yoghurt. More recently Rist and Khoury[66] isolated from Egyptian leben two bacilli to which they gave the names *Strepto-bacillus lebenis* and *Bacillus lebenis*. Grigoroff[27] and Cohendy[13] isolated similar organisms from Bulgarian fermented milk. These various bacteria are undoubtedly nearly or quite identical and are all included under the name *Bacillus bulgaricus*, now generally adopted. More strict adherence to the commonly accepted rules of bacteriological nomenclature would retain the name *Bacterium caucasicum* proposed by Beyerinck. Recent work by Hastings[30] and by Heinemann and Hefferan[34] indi-

cates that this bacterium is not peculiar to the eastern fermented milks, but is widely distributed, having been isolated from milk, soil, saliva, feces, and various soured foods. White and Avery [76] believe that this bacterium is the representative of a group of closely related bacteria which they divide into two types on the basis of their activity in milk and the nature of the lactic acid formed. The characteristics of the typical culture may be summarized as follows:

Morphology.—Slender rods 2 microns to 6 or 8 microns in length, breadth usually about 1 micron, flagella and spores absent. Long chains frequently occur and apparently vary with different strains and conditions; pseudobranching has been observed. Very long threads without apparent division are frequently observed in old cultures. Living cells are gram positive, dead cells are gram negative.

Growth on artificial media.—One of the most striking features is its inability to grow on ordinary media. It grows on whey, malt, and slowly on whey agar and certain specially prepared media. The colonies on whey agar are masses of tangled threads resembling colonies of the anthrax bacillus. Gelatin is not liquefied.

Relation to oxygen.—Most varieties grow equally well in the presence or absence of oxygen.

Temperature relations.—The maximum temperature is near 45° C. (113° F.). The minimum growth temperature varies with different members of the group, but it is always comparatively high. Most varieties grow very slowly at 25° C. (77° F.), but some grow at 20° C. (68° F.). Hastings and Hammer[31] state that at 20° C. (68° F.) it forms 4 per cent acid in milk as compared with a maximum of 3 per cent at 37° C. (98° F.). According to White and Avery [76] it is killed by an exposure of fifteen minutes at 60° C. (140° F.).

Fermentation of sugars.—Many of the sugars are fermented, but statements of different workers are conflicting. It is probable that this property varies in different varieties.

Milk.—The action of this organism on milk distinguishes it from all other known bacteria. At the optimum temperature milk is curdled in a few hours with a rather soft curd, frequently somewhat slimy, which does not separate from the whey even on long standing. In twenty-four hours the milk may show acidity equivalent to nearly 2 per cent of lactic acid, and on standing several days this may become about 3 per cent. The most active of the ordinary lactic-acid bacteria seldom exceed 1 per cent lactic acid. The more active type of *Bacterium caucasicum* forms the inactive lactic acid, while the levorotatory acid is produced by the type forming acid more slowly. Small amounts of other organic acids are formed, and traces of alcohol.

This bacterium is evidently the essential organism of yoghurt, matzoon, ceiddu, leben, and similar fermented milks. Other bacteria are always present, some of them habitually and others only occasionally. Some of these may have an influence on the flavor while others are inert. It is probable that there are none, with the exception of *Bact. caucasicum*, that could not be replaced by other species without appreciably affecting the results. Different localities have doubtless developed slightly different varieties of fermented milk due to different combinations of bacteria or of bacteria and yeasts. The Egyptian leben is reported to contain alcohol, but not in sufficient quantities to produce an effervescence such as is observed in kefir or kumiss. One of the ordinary lactic-acid bacteria seems always to be present with the *Bact. caucasicum*, and it is probable that if it is not essential it is of some assistance in starting the lactic fermentation and, especially if the temperature is low, in suppressing contamination before the *Bact. caucasicum* has time to develop sufficient acid to check extraneous bacteria.

Hastings and Hammer [31] could not detect evidences of proteolytic enzyms by the usual tests, but found in old milk cultures a distinct peptonization of the casein which was not due to the action of the acid. This change is so slow and so small that it can not be considered as having any influence on the digestibility of the milk. Otherwise the only changes in the milk constituents are in the conversion of the sugar to lactic acid and very small amounts of volatile acids and traces of alcohol.

"Yoghurt buttermilk" is now sold in several cities, and the growing demand will doubtless soon extend its manufacture more generally. In making yoghurt in this country better results are secured by using with the *Bact. caucasicum* a culture of an ordinary lactic-acid organism such as is used in making buttermilk. *Bact. caucasicum* growing alone in milk forms usually a rather slimy tenacious curd which can not be broken up into the smooth creamy condition essential to a good buttermilk. If this organism is grown in combination with the ordinary lactic-acid organism, a more friable curd is obtained and the sliminess is not so evident. The two organisms can be carried in mixed culture only with great difficulty, as the high acid soon suppresses the ordinary form. The most satisfactory results can be obtained by making buttermilk in the ordinary way and churning it with an equal quantity of milk curdled with the yoghurt organism. This procedure gives the desirable texture of buttermilk and a distinctive flavor.

If a culture can be obtained, yoghurt can be made in the home with little difficulty. Heat the milk—for example, one quart—by holding the bottle submerged to the level of the milk in boiling water for a half hour. Cool the milk, slowly at first, by displacing the hot water

with cold water. When the milk is cooled to about 40° C. (104° F.) add one teaspoonful of the culture. The milk should be held at a temperature as near 40° C. (104° F.) as possible. If the temperature is higher the curd is likely to be lumpy and tough; if the temperature is lower than 37° C. (98° F.) the fermentation is slower and the danger of the development of contaminating organisms is greater. The proper temperature is easily maintained by the use of one of the vacuum jacketed bottles now in general use. When these are available the procedure may be varied slightly from that given above. It may be more convenient to heat the milk in a double boiler ordinarily used for cooking cereals. Keep the water boiling for a half hour. It may be cooled by filling the outer receptacle with cold water. Cool the milk to 40° C. (104° F.), transfer to the insulated bottle, and add a teaspoonful of the culture. After about eighteen hours the milk is curdled and ready for use. It should be transferred to a clean milk bottle, capped or covered with an inverted glass, and put on ice to cool. If the yoghurt is not kept cold the acidity will continue to develop until it becomes unpalatable. The insulated bottle should be thoroughly washed and rinsed with boiling water and the cork stoppers should be boiled frequently. The process is then repeated, using for a culture a teaspoonful of the freshly curdled milk. The yoghurt may be made more palatable by adding to two parts of the yoghurt one part of cold water, or, better still, cold charged water, which can be bought in siphons at drug stores. Sugar and lemon juice or other fruit flavors or chocolate sirup may also be used for this purpose. The sugar should be added in the form of a sirup, as granulated sugar dissolves very slowly in the cold yoghurt. If the yoghurt has gas bubbles or a yeasty or a bitter flavor it has become contaminated with foreign organisms. The contamination may be removed by fermenting the milk at a higher temperature for three or four days, thus producing conditions unfavorable to the growth of the foreign organisms. The milk should be put into the insulated bottle at 49° C. (120° F.). This will give a high acid and a lumpy curd, but the contamination should be eliminated in three or four days.

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